Final Waikele Stream Bioassessment

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Why Assess Hawaii's Streams?

Water has been a precious resource throughout history in the Hawaiian islands and the United States. Ancient Hawaiians depended on streams for many reasons from drinking water to irrigation of taro (Handy and Handy 1972). They also collected native stream animals, such as the 'o'opu (fish) and 'opae (shrimp or prawns), for food. This resource continues to be of great importance in present day. The goal of the 1972 Federal Clean Water Act is to achieve "fishable and swimmable" waters for all Americans by restoring and maintaining the chemical, physical, and biological integrity of the Nation's surface waters (33 U.S.C. §1251). The Hawaii State Water Code (Hawaii Revised Statutes (HRS), Chapter 342D) states that the waters of the state are held for the benefit of citizens who have a right to have the waters protected for their use. In an effort to meet these national and state goals, the Hawaii State Department of Health (DOH) adopted regulations (Hawaii Administrative Rules (HAR) Chapter 11-54, Water Quality Standards) that designate uses, set water quality criteria and establish an antidegradation requirement for all state waters (Burr 2001a; 2001b).

The DOH is required under Section 303(d) of the federal Clean Water Act to generate a list of surface waters that are exceeding or will likely exceed state Water Quality Standards. This List is known as the Clean Water Act §303(d) List of Water Quality-Limited Segments and is sometimes also referred to as the state's List of Impaired Water Bodies or simply the List. The List must be revised every two years using readily available data, and the U.S. Environmental Protection Agency (EPA) must approve each revision of the List.

After a waterbody becomes an official component of the List, the state is then required to determine the Total Maximum Daily Load (TMDL) of pollutants for the water bodies that are on the List. Each TMDL establishes the amount of a certain pollutant that a waterbody can receive in a given period of time without the waterbody exceeding the water quality standard criteria for that pollutant. As part of the TMDL process, DOH calculates load allocations for various pollutant sources, such as storm drain systems and other surface runoff sources. Because TMDLs are more difficult to compute for coastal waters, and streams carry many pollutants into coastal waters, the Department of Health is examining the chemical, physical and biological integrity of the streams first. Reduction of the pollutant load to the streams to TMDL levels should result in improved water quality in coastal waters, especially in enclosed waterbodies with limited circulation. The DOH believes that improving the water quality of the streams will improve the water quality in at least a portion of the adjacent coastal waterbodies. If the water quality in the coastal waters continues to exceed Water Quality Standards following the establishment and implementation of TMDLs for the streams, then TMDLs will be established for the coastal waterbodies themselves (Burr 2001a; 2001b).

Habitat and Biological Assessment of Hawaii Streams

The EPA promotes the use of rapid bioassessment protocols as screening tools to determine if streams support designated aquatic life uses, to characterize the location and severity of use impairment and to help identify the causes of use impairment. Rapid bioassessment protocols compare habitat characteristics and biological metrics with reference conditions (Plafkin et al. 1989 as cited in Burr 2001a).

The Hawaii State Department of Health (DOH) will continue to use habitat and biotic integrity scores to complement existing physical and chemical criteria in the Water Quality Standards, to evaluate streams proposed for listing or delisting under section 303(d) of the Clean Water Act (CWA) and to aid in the preparation and implementation of TMDLs (Burr 2001a; 2001b). By collecting enough data to correlate habitat and biological integrity scores with the attainment of physical and chemical criteria, it may ultimately be possible for the EPA to approve Hawaii TMDLs related to habitat and biotic integrity. Currently, narrative bottom criteria for streams exist in the state Water Quality Standards. These criteria state, "The director shall prescribe the appropriate parameters, measures, and criteria for monitoring stream bottom biological communities including their habitat, which may be affected by proposed actions. Permanent benchmark stations may be required where necessary for monitoring purposes. The water quality criteria for this subsection shall be deemed to be met if time series surveys of benchmark stations indicate no relative changes in the relevant biological communities, as noted by biological community indicators or by indicator organisms which may be applicable to the specific site" (HAR 11-54-05.2(b)(2)(E)).

Most Hawaiian stream systems are short and steep and have low but flashy flows. Uniquely adapted native animals have evolved in these conditions – some even have the ability to climb waterfalls. These species depend upon heavy rains for reproductive success, and all exhibit an amphidromous lifecycle where fish lay eggs in freshwater, larvae are carried downstream and drift as oceanic plankton and juveniles return to streams (Kinzie 1990 as cited in Burr 2001a). Native aquatic macrofaunal species are used as biological indicators of stream quality in Hawaii because they are known to be sensitive to environmental degradation, taxonomically unique, readily identifiable, specifically adapted to Hawaiian stream environments and found on all islands (Kido et al. 1999 as cited in Burr 2001a). Various habitat characteristics are also evaluated to assess the conditions of the environment in terms of the support it provides for the native species (Burr 2001a).

Metric scores were developed on an ecoregional scale (all main Hawaiian islands), using a data set that includes sites that range in condition from least impaired to highly degraded (Kido 2002 as cited in Burr 2001a). State reference conditions are the set of highest index scores (100%) computed in the state. The key to interpreting scores assigned to sites using the bioassessment protocol is to compare them to reference conditions (Table 1).

Table 1. ***Guideline values for interpreting attainment of aquatic life uses in Hawaiian streams***

Habitat	Biological
(% of reference)	
<50% = nonsupporting	<30% = impaired
50-75% = partially supporting	30-70% = moderately impaired
75% = supporting	70% = unimpaired

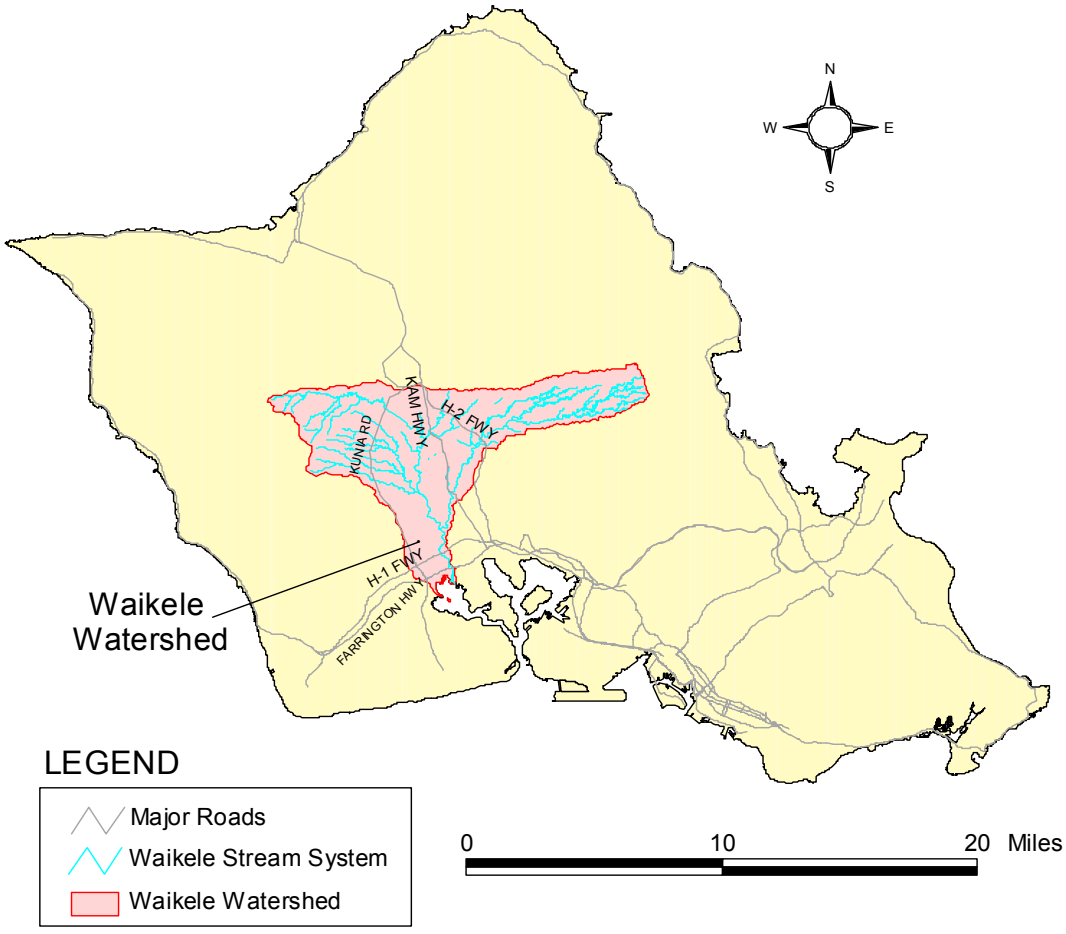
When assessed together, the habitat characteristics and biological metrics help indicate the degree of impairment of a stream and, when evaluated with various physical and chemical parameters, can assist in the development of TMDLs for the stream (Burr 2001a; 2001b). Once TMDLs have been established, implementation measures will be developed to restore the chemical, physical and biological integrity of the stream, in line with Clean Water Act goals. When reviewing these biological assessments, it is important to understand that degradation of water quality is not the only cause of biological impairment in streams. Alterations of stream geomorphology, flow and species composition are just a few factors that can impact biological communities in streams.

Assessment of Habitat and Biological Integrity of Waikele Stream

Waikele Stream is the fourth stream in Hawaii for which the Department of Health (DOH) has conducted a bioassessment as part of a TMDL study. The DOH conducted the first three bioassessments on three windward Oahu streams: Waimanalo Stream (Smith 1998), Kawa Stream (Burr 2001b) and Kaneohe Stream (Burr 2001a). The TMDL for Waikele Stream is one of many TMDLs that will be completed for impaired streams that flow into Pearl Harbor. If the water quality in the Pearl Harbor estuary continues to exceed Water Quality Standards following the establishment and implementation of TMDLs for the streams that feed into it, TMDLs will be established for Pearl Harbor itself. This bioassessment of Waikele Stream was conducted in coordination with chemical and physical measurements taken for the TMDL program. DOH intends for scientists, government agencies and community members to utilize this assessment in conjunction with the Waikele TMDL study as they focus their activities to reduce pollution loads and improve water quality.

Waikele Stream Watershed, one of the largest watersheds on Oahu, drains both the eastern Waianae and western Koolau mountains and flows into the West Loch of Pearl Harbor (Figure 1). The Watershed drains approximately 46 square miles. The Hawaii Stream Assessment (HSA) code for the Waikele Stream system is 3-4-10 (CWRM and NPS 1990).

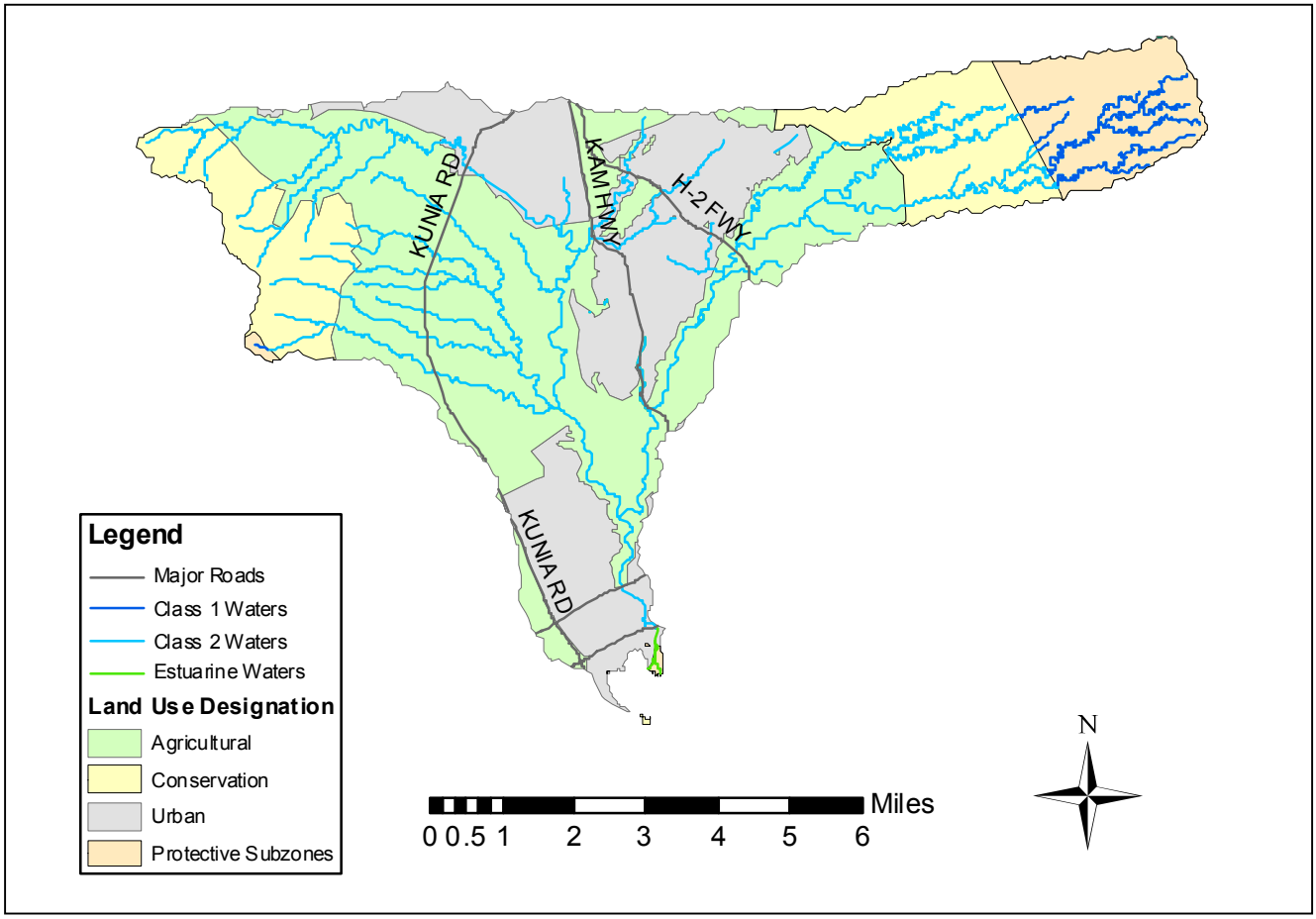
Figure 1. ***Location of Waikele Watershed***



Many diverse land uses influence the Waikele Stream system (Figure 2). The lowest elevation portions of the Waikele Stream Watershed are zoned for urban land use. Much of the middle portions of the watershed are zoned for agriculture with some areas zoned urban as well. The uppermost portions of this watershed are zoned conservation. Much of the land in the Waikele watershed is owned by the military, Army and Air Force. The Navy also owns large parcels near Waikele Shopping Center, which are currently leased by the Fluor Corporation.

Small sections of the headwaters of some of the tributaries to Waikele Stream originate in the Protective Subzones of the Conservation District or other reserve or park areas; therefore, these sections of the stream are classified as Class 1 Perennial Streams under Hawaii's Water Quality Standards (Figure 2). According to the Water Quality Standards, these waters are to remain in their natural state with an absolute minimum of pollution from any human-caused source. The most sensitive use to be protected in these reaches is protection of native breeding stock. TMDL implementation goals for habitat and biotic integrity, based upon the Water Quality Standards, are established for these Class 1 segments in this report, using survey data from the Upper Kipapa Site.

Figure 2. ***Land Use and Stream Classification of Waikele Stream***



Previous Studies in the Waikele Stream Watershed

Multiple environmental surveys have been conducted in the Waikele Stream Watershed; however, only a few of these have characterized the biological and habitat characteristics of the stream itself. A 1978 study by Timbol et al. recorded mainly introduced fishes such as topminnows, tilapia and catfish. Rare sightings of ‘o’opu nakea (*Awaous guamensis*) were also documented (as described in AECOS 1989). According to Timbol et al., ‘o’opu nakea and ‘opae oeha’a (*Macrobrachium grandimanus*) were also reported in the lower reaches of Waikele Stream in the 1970s. In 1986, Timbol and Maciolek again documented the presence of many introduced fishes and the native aquatic species, *Awaous guamensis* and *Macrobrachium grandimanus* (as cited in AECOS 1992). Subsequently, AECOS, Inc. completed a few short, confined surveys on the Kipapa tributary near the H-2 viaduct that revealed only introduced species, including common guppies (*Poecilia reticulata*) and green swordtails (*Xiphophorus helleri*) (1989).

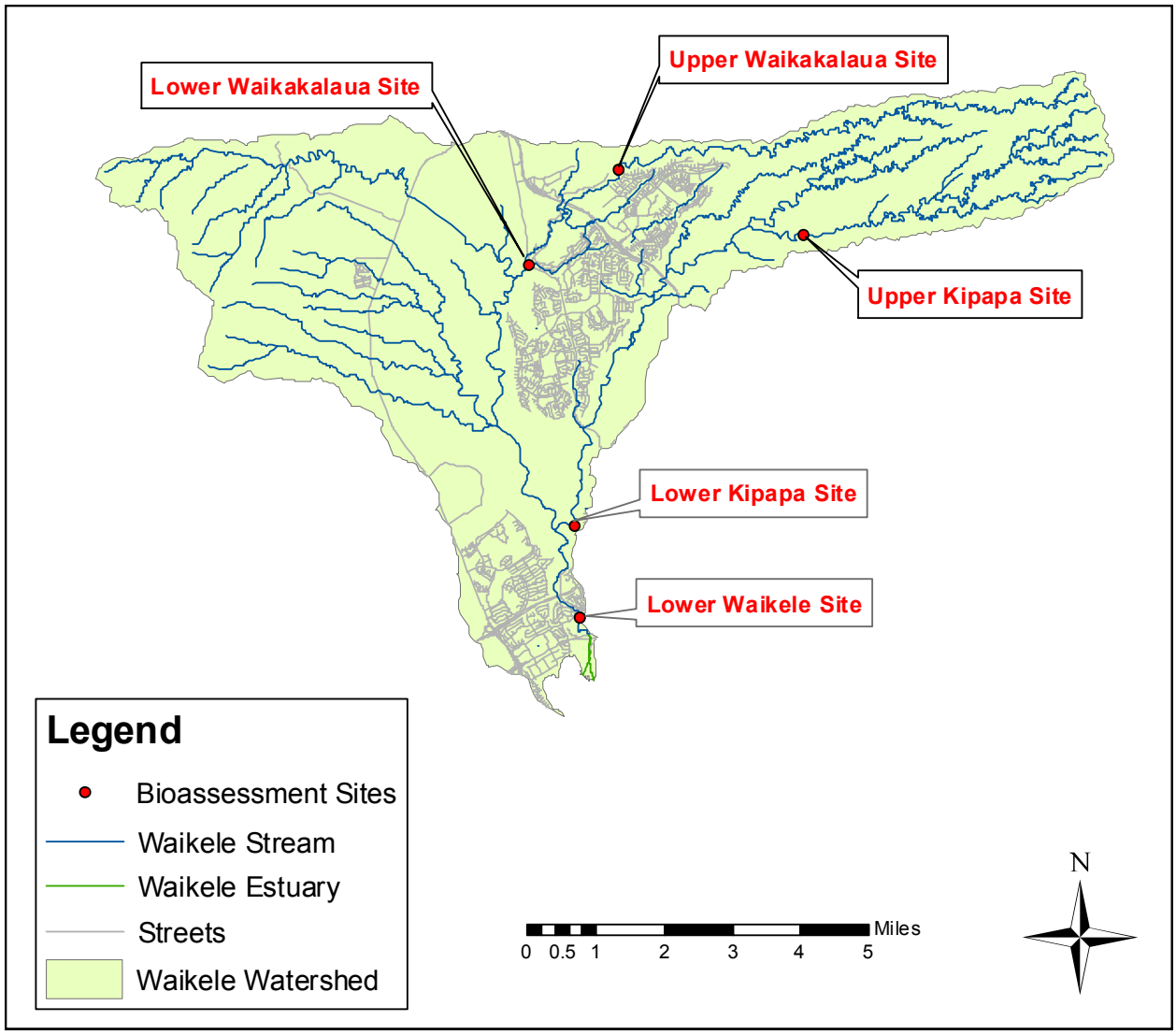
A 1991 survey reported introduced fishes, such as topminnows (*Poecilia* spp.) and dojo (*Misgurnus anguillicaudatus*), in the middle reaches of the Waikakalaua Tributary and ‘o’opu nakea (*Awaous guamensis)* at approximately 1380 feet elevation (Dames & Moore as cited in AECOS 1992). In 1993, Environmental Technologies International (ETI) documented ‘o’opu naniha (*Stenogobius hawaiiensis)* and ‘o’opu nakea juveniles as well as various size classes of ‘o’opu ‘akupa (*Eleotris sandwicensis)* and aholehole (*Kuhlia sandvicensis)* below the Farrington Highway Bridge. ‘Opae oeha’a were also observed in the lower reaches of Waikele Stream, and many life stages of ‘o’opu nakea were found in the lower, middle and upper reaches (Kipapa Tributary) of Waikele Stream (ETI 1993). ‘opae kala’ole (*Atyoida bisulcata*) were reported in Kipapa Stream in a 1996 study related to the Air Force POL pipeline (EA Engineering, Science, and Technology). In a 1997-1998 survey of the lower and middle reaches of Waikele Stream, declining numbers of adult *A. guamensis* and *S. hawaiiensis* were reported (Englund and Filbert 1999). Contrary to the 1993 ETI study, post-larvae of these species were not detected. Topminnows and bristlenose catfish (*Ancistrus cf. temminckii*) were abundant during this sampling effort, and the introduced shrimp, *Neocaridina denticulata sinensis*, were documented in large numbers. The Division of Aquatic Resources (DAR), which is part of the state Department of Land and Natural Resources, also conducts many aquatic assessments throughout the state. DOH staff could not obtain any of the DAR reports for Waikele Stream despite multiple attempts.

These studies compose the majority of the disjointed body of knowledge with regards to the aquatic fauna of Waikele Stream. Many of the studies cited above were qualitative assessments of the stream system or confined to small isolated sites on the stream. This DOH study applies a quantitative, multi-metric approach to evaluating the habitat and biotic conditions at multiple sites in the Waikele Stream system. The study sites were chosen based on land use, stream classification and stream morphology.

Site Descriptions and Background

Personnel from the DOH conducted biological assessments at each of five sites on Waikele Stream: Lower Waikele, Lower Waikakalaua, Upper Waikakalaua, Lower Kipapa and Upper Kipapa (Figure 3). Each assessment site roughly corresponds to a DOH Clean Water Branch water quality sampling location and/or is representative of a larger section of the stream with respect to habitat, biological community and expected response to human degradation.

***Figure 3.* Habitat and Biological Assessment Sites in Waikele Stream**



Upper Kipapa Site

Figure 4. Upper Kipapa Site

The Upper Kipapa station is located N 21°28'13", W 157°57'40" upstream of USGS gaging station 16212800 near Wahiawa. The site has an elevation of about 700 feet. The Hawaii Stream Assessment code for Kipapa is 3-14-10.01. The USGS has peak and daily stream flow records from 1957 to present and water quality samples dating as early as 1968 and as recent as the year 2000. The land surrounding and above the site is primarily forested (Figure 4). DOH personnel conducted a visual assessment of the site in March of 2002 and a biological assessment of the site in June 2003.

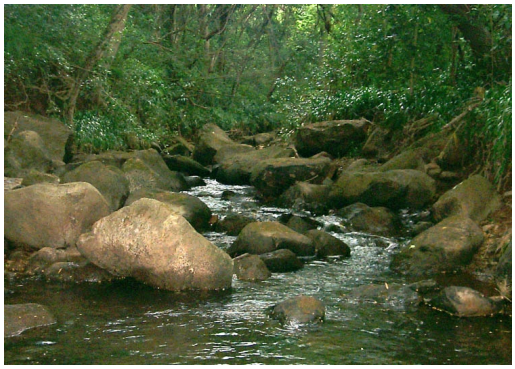
Lower Kipapa

Figure 5. Lower Kipapa Site

The Lower Kipapa Site is located at N 21° 24' 27.0'' and W 158° 00' 50.01'' with an elevation of approximately 120 feet above sea level (see Figure 5). The watershed for the Lower Kipapa site is predominately agricultural and military land with some urban (residential) uses. Military contractors have conducted a few surveys of aquatic sampling sites upstream of this site when investigating the impact of leaks in an Air Force pipeline and associated storage tanks near the stream (EA Engineering, Science, and Technology. 1996; The Environmental Company 2001). DOH personnel conducted a visual assessment of the Lower Kipapa Site in April 2002 and a biological assessment of the site in September 2003.

Upper Waikakalaua Site

Figure 6. Upper Waikakalaua Site before Major In-Stream Construction



The Upper Waikakalaua bioassessment site is located at N 21° 28' 57.1'' and W 158° 00' 13.6'' and about 760 feet above sea level. The site is near the end of Wikao Road in the midst of a residential housing development above the Mililani Tech Park area. During the assessment period, active construction was occurring both above and below the study site. A large section of

streambank upstream of the site was graded and left uncovered with bare soil exposed to the elements. Additionally, one of the banks within the site was lined with a stone and concrete revetment down to the streambed. The initial visual assessment was conducted prior to this in-stream construction in May of 2002 (Figure 6). The biological assessment was conducted in September of 2003. The DOH Clean Water Branch and our TMDL contractors (Oceanit, Inc.) collected multiple water quality samples below the site for TMDL development (Figure 7). Above the housing development the land area is forested. Construction employees, who worked near the sampling site, reported that the streambed was dry at this site during a brief period during the summer months of 2003.

Figure 7. Upper Waikakalaua Site after Major In-Stream Construction

Lower Waikakalaua Site

The Lower Waikakalaua bioassessment site is located at N 21° 27' 49.6'' and W 158° 01' 25.2'' at approximately 540 feet above sea level. The site is located off Kamehameha Highway near a sewage pumping station and upstream of U.S. Geological Survey gaging station number 16212700. The USGS has peak stream flow records from 1958 to present and has conducted other studies at this site, including water-column, bed sediment and fish tissue studies. The DOH Clean Water Branch and our TMDL contractors (Oceanit, Inc.) collected multiple water quality samples below the site for TMDL development. Urban, agricultural and forested areas dominate the land use in the approximately 7 square miles of land that are drained by this part of the watershed (USGS 2003). Military land borders the western edge of the site while a sewage pumping station borders the eastern edge. A residential community lies upstream of the site. A visual assessment and a bioassessment were conducted in December 2002. On multiple occasions following this assessment, DOH staff documented that the stream channel at this site was dry (Figure 8).

Figure 8. Lower Waikakalaua Site during Dry Conditions

Lower Waikele Site

The Lower Waikele bioassessment site is located at N 21° 23' 11.3'' and W 158° 00' 44.7'' below the Waipahu Street bridge and above the U.S. Geological Survey's (USGS) gaging station (16213000). The site has an elevation of approximately 40 feet above sea level. The USGS has peak and daily stream flow records at the gaging station for most dates from 1951 to present and water quality data sporadically from 1967 to 2002. Real-time stream flow data is also available on the USGS website. The USGS also has

Figure 9. Lower Waikele Bioassessment Site

conducted other studies at this site and a site upstream near the H1 freeway, including water-column, bed sediment and fish tissue studies. The DOH Clean Water Branch and our TMDL contractors (Oceanit, Inc.) collected multiple water quality samples below the site for TMDL development. Initially, the DOH had hoped to conduct biological and habitat assessments directly above the gaging station. Upon assessment in April 2002, the initial site proved too deep for an efficient and complete assessment. A new site was delineated a few hundred meters upstream of the gaging station closer to the Waipahu Street bridge. DOH personnel completed a visual assessment of the site in June 2003, and a bioassessment of the site in September 2003 (Figure 9).

Methods

As an initial evaluation at each site, the Hawaii Stream Visual Assessment Protocol (HSVAP) was conducted (Kelley 2001). This protocol involves visual assessment of multiple habitat characteristics, including stream substrate, canopy cover and riparian area. The protocol also involves scoring ten habitat metrics (see Table 2). Then, using the Hawaii Stream Bioassessment Protocol (HSBP), ten characteristics representative of the quality of stream habitat and ten metrics to measure the biotic integrity from the individual, population and community levels of ecological organization were evaluated (see Table 3).

Each biological assessment followed the Hawaii Stream Bioassessment Protocol (HSBP). Electrofishing techniques (Figure 10) were utilized in place of underwater visual census only when waters were (1) thought to be polluted to a point that posed a risk to human health, (2) too turbid to examine fish adequately underwater, (3) dominated by small introduced fish that were difficult to count underwater or (4) not deep enough to snorkel. Only trained and closely supervised personnel with proper safety equipment were allowed to conduct the electrofishing for this sampling effort.

Figure 10. Electrofishing Training in Manoa Stream

The length of each study site was generally 20 times the mean width of the stream, or 100 meters, whichever was longer. At some sites, the water was too deep for use of the electrofisher as an assessment tool and the water was too turbid or too polluted for underwater visual census; therefore, some of the site lengths were slightly shorter than 100 meters. Each site was divided into four equal-length quadrants within which each of the 20 different metrics was evaluated. The overall score for the site was an average of the quadrant scores at each site.

Table 2. HSVAP Habitat Metrics

Metric	*Optimal Condition*
Turbidity	Water very clear; objects visible at depth to the bottom.
Plant growth	Water clear with no significant algal scum or microalgae; rocks may be slimy but algae not obvious
Channel Condition	Natural Channel
Channel Flow Alteration	No withdrawals, diversions or stormwater/agricultural water discharges entering the segment.
Percent Embeddedness	< 10% embeddedness
Bank Stability	> 90% Stable (not bare or erodable)
Canopy/Shade	Mixed canopy, 20 - 80% cover
Riparian Condition	Riparian area same width as floodplain, diverse vegetation or stream is naturally incised, stable banks. Undisturbed.
Habitat Available for Native Species	5 habitat types available (seeps/springs, pools, runs, riffles and cascades)
Litter/trash	No litter or trash is present.

Table 3. HSBP Habitat and Biological Metrics

Habitat Metrics	
Metric	*Optimal Condition*
Habitat Availability	Heterogeneous habitat provides access for stream organisms to a variety of habitat types and hydrologic regimes.
Substrate Embeddedness	Maximally exposed cobble and boulder substrate is abundant and limited quantities of sediment exist in the stream.
Fine and Course Particulate Organic Matter	Most organic matter is degraded, suspended, and transported out of the watershed.
Velocity-Depth Combinations	Heterogeneous patterns of stream flow velocity and depth provide a mix of hydrologic regimes that create a variety of physical microhabitats.
Channel Flow Status	The wetted stream width is nearly as large as the bank full width, thus providing habitat for aquatic organisms.
Channel Alteration	No alteration; maintains physical heterogeneity and natural habitat.
Bank Stability	Both banks are intact and show no signs of erosion, maintaining natural habitat heterogeneity.
Riparian Vegetative Zone Width	Intact and functional riparian zones have widths at least four times the mean width of the stream to retard landscape erosion and act as buffers against pollutants entering the water.
Riparian Understory Coverage	Intact understory plants prevent soil erosion and movement into the stream and maintain habitat for stream organisms.
Percent Native Riparian Plant Coverage	High percent of native plants indicate natural riparian conditions and high riparian quality. However, intact native riparian areas are uncommon in Hawaii and 12.5 percent coverage is the optimal expected coverage today.
Biological Metrics	
Metric	*Optimal Condition*
Number of Native Amphidromous Macrofauna	Native species richness is high, but dependent upon slope gradient.
Percent Contribution Native Taxa	Native aquatic species are numerically dominant (>75 percent) and except for the amphidromous alien prawn, *Macrobrachium lar*, alien species are entirely absent.
Percent Native Fish	At least 50 percent of the sample population of fish is expected to include *Lentipes concolor* or *Sicyopterus stimpsoni*, native species highly sensitive to environmental degradation.
Sensitive Native Fish Density	High densities of sensitive native fish are found in robust fish populations.
Sensitive Native Fish Size	Fifty percent of the sampled population of sensitive native fish should have a total length of at least 6.0 cm, as an indication of robust biotic integrity in terms of reproductive potential, trophic dynamics, species interactions, and environmental support.
***Awaous guamensis* Size**	*Awaous guamensis* is relatively common even in degraded streams. Fifty percent of the sampled fish population should have a total length of at least 8.0 cm, as an indication of robust biotic integrity in terms of reproductive potential, trophic dynamics, species interactions, and environmental support.
Total Native Fish Density	Higher total native fish densities correlate with more natural ecological functioning, higher environmental quality, lower numbers of alien species, and reduced human influence.
Community Weighted Average	Native species dominate the community and alien species are either absent or in very low proportionate abundance.
Number of Alien Taxa	Streams either have no alien species present or low numbers of *M. lar*.
Percent Tolerant Alien Fish	Alien species that are highly tolerant of degraded conditions are in low proportionate abundance.

Results and Discussion

For the Hawaii Stream Visual Assessment Protocol (HSVAP), ten habitat metrics were evaluated, and a score ranging from 0 (poor) to 2.0 (good) was assigned to the station. For the Hawaii Stream Bioassessment Protocol (HSBP), ten habitat characteristics and ten biological metrics were evaluated at each station and then a score, expressed relative to the statewide reference condition, was assigned to the station.

Upper Kipapa Site

Figure 11. Scoring the HSVAP Protocol at the Upper Kipapa Site

Overall, the Upper Kipapa site scored "High" for habitat quality, using the Hawaii Stream Visual Assessment Protocol (HSVAP). All segments had low turbidity and, thus, scored in the very high range. Algal growth was relatively low at this site, scoring in the high to very high range. The channel condition and channel flow alteration scored in the very high range throughout the site. Embeddedness scores ranged from medium in the segments with slower moving water to very high in the segment dominated by cascades. Bank stability scores ranged from medium to very high; this divergence was likely due to the presence of human and feral pig trails close to the stream bank in one of the segments. Riparian condition scored in the high to very high category in all segments. Large ti plants, guava, mango trees and native ferns dominated the riparian vegetation. The canopy cover was open. Using this protocol, canopies with less than 20% cover obtain a score of zero (0). Therefore, two of the segments scored in the low range, and two scored in the very high range. This metric may need review since native canopies are thought to be relatively open. Many types of stream habitat were available in this segment, including pools, runs, riffles and cascades; therefore, available habitat scored in the high to very high range for all segments. No litter or trash was observed at the site; therefore, the Litter/Trash metric consistently scored very high.

HSVAP Score:
Score ..... 1.7 out of 2.0
Average Habitat Rating ..... High

The site also had "Supporting" scores for habitat under the Hawaii Stream Bioassessment Protocol (HSBP). The site had consistently high scores for habitat availability, channel alteration, riparian vegetation width, embeddedness and soil presence. Bank stability scores were moderate; feral pig and human trails likely contributed to these scores. It should be noted that the protocol sets a high standard for bank stability with 0% erosion as the target. The presence of coarse organic matter from invasive trees such as guava contributed to a moderate score for organic matter as well. Velocity-depth scores were also moderate due to the lack of slow, deep environments and moderate depth faster moving waters. Channel flow status scored low, likely due to summer drought conditions.

HSBP Habitat Score:
Score 161.5
Percent of statewide reference..... 81%
Estimated degree of attainment of aquatic life use ..... Supporting

Despite high scores for habitat, this site scored low for biotic integrity, using the HSBP methodology for assessment. This site was dominated by alien species; no native species were found during the sampling effort. Topminnows, such as the common mosquito fish, *Gambusia affinis*, and *Poecilia reticulata* (also known as guppies) have invaded the site. Many bristlenose catfish (*Ancistrus* sp.), a Chinese catfish (*Clarias fuscus*) and a few dojo (*Misgurnus anguillicaudatus*) were also found at the site. Introduced grass shrimp, *Neocaridina denticulata sinensis*, were also present.

HSBP Biological Score:
Score 15
Percent of statewide reference..... 27%
Evaluation of aquatic life ..... Impaired

Lower Kipapa Site

Overall, the Lower Kipapa site scored "Medium" for habitat quality, using the Hawaii Stream Visual Assessment Protocol (HSVAP). Plant growth scored mainly in the high range throughout the site while channel condition scored mostly in the very high range. The site consistently scored in the very high range for channel flow alteration and channel condition. The site scored mainly in the low range for percent embeddedness. Bank stability ranged from medium to high to very high. The average site score for canopy was in the medium category. The canopy score for one of the segments scored zero due to heavy canopy, which brought down the average site score significantly. Riparian condition remained relatively constant scoring in the high category. Habitat available scores ranged from low in slower water segments to very high in the segments with swifter riffle/run habitat. Trash and turbidity scores were in the low category for the entire transect.

Figure 12. Linda Koch wading through the Lower Kipapa Site after conducting the HSBP

HSVAP Score:
Score ..... 1.3 out of 2.0
Average Habitat Rating ..... Medium

The site had "Partially Supporting" scores for habitat under the Hawaii Stream Bioassessment Protocol (HSBP). The site had suboptimal scores for habitat availability, and organic matter. The site had marginal scores for embeddedness and soil presence. The riparian vegetation width was low due to intentional clearing. Bank stability scores were poor because the area was highly eroded perhaps due to intermittent nature of the stream and the lack of riparian area adjacent to the stream. The site scored optimally for velocity-depth combinations. Channel flow status scored high as this site was under storm flow conditions. Channel alteration scores were also high since the segment did not appear to be channelized.

Habitat:
Score 107
Percent of statewide reference..... 54%
Degree of attainment of aquatic life use ..... Partially Supporting

The HSBP methodology showed the Lower Kipapa site to be biologically impaired. Sampling at this site recovered only alien aquatic fauna. Topminnows, such as the common mosquito fish (*Gambusia affinis*), guppies (*Poecilia reticulata*), mollies (*Poecilia* spp.) and green swordtails (*Xiphophorus helleri*) were collected at the site. Bristlenose catfish, crayfish (*Procambarus clarkii*) and *Macrobrachium lar* (also known as the Tahitian or Pacific prawn) were also collected. The introduced grass shrimp, *Neocaridina denticulata sinensis*, were also abundant.

Biological metrics:
Score 15
Percent of statewide reference..... 27%
Evaluation of aquatic life ..... Impaired

Upper Waikakalaua Site

Figure 13. Milky Color at Upper Waikakalaua Site

Overall, the Upper Waikakalaua site scored "High" for habitat quality, using the Hawaii Stream Visual Assessment Protocol (HSVAP). The water at the site had a distinctive milky white tint; in spite of this, the site scored very high for turbidity because objects were visible at depth. Plant growth and channel flow alteration scores were also in the "very high" category. Channel condition scores, riparian condition and bank stability scores were slightly lower because of alteration to the bank and channel from preliminary construction for a housing development. Embeddedness scores ranged from low in slower riffles and runs to high in the faster habitats. Canopy, Habitat Available and Litter/Trash scores were high throughout the site.

HSVAP Score:
Score ..... 1.6 out of 2.0
Average Habitat Rating ..... High

The HSBP methodology was applied many months after the initial visual assessment to characterize the site. Unfortunately, major bank alterations extending into the channel width were made to the site. An additional HSVAP assessment was not conducted for this report. A significant decline in the score would be expected, considering DOH staff observed heavy siltation and other indicators of habitat degradation following construction. This site had "Nonsupporting" scores for habitat, using the HSPBP methodology. Habitat availability was suboptimal. Organic matter scores were marginal. Velocity-depth scores were suboptimal. Channel flow status was optimal. Channel alteration scores were in the optimal category. Bank stability, embeddedness and soil presence scores were poor. Riparian vegetation scores were marginal.

Habitat:
Score 92.5
Percent of statewide reference..... 46%
Degree of attainment of aquatic life use ..... Nonsupporting

The HSBP methodology showed the Upper Waikakalaua site to be biologically impaired. Sampling at this site recovered only alien aquatic fauna. Topminnows, such as the guppies (*Poecilia reticulata*) and green swordtails (*Xiphophorus helleri*) were collected. Bristlenose catfish were also present, and the introduced grass shrimp, *Neocaridina denticulata sinensis*, were abundant.

Biological metrics:
Score 15
Percent of statewide reference..... 27%
Evaluation of aquatic life ..... Impaired

Lower Waikakalaua Site

Figure 14. Trash at Lower Waikakalaua Site

The Lower Waikakalaua site was dry when DOH personnel conducted the HSVAP evaluation. Due to the lack of water, most of the elements of the protocol could not be scored and an overall score could not be generated. Nevertheless, preliminary investigations showed a lack of both bank stability and adequate riparian area. The vegetation that was present included a variety of introduced grasses, shrubs and trees, including strawberry guava, Christmas berry, California grass, eureka palm, false heather, java plum, alocasia, clidemia, ginger, wedelia and one banana plant. One kukui nut tree was also documented. Trash was evident throughout the site, including a large, rusted storage tank and a rubber chicken (Figure 14).

The Hawaii Stream Bioassessment Protocol (HSBP) habitat score for this site was "Nonsupporting." The site scored poorly for embeddedness, presence of organic matter and cobble/boulder vs. soil and scored in the marginal category for bank stability, riparian understory, habitat availability, channel flow status and velocity-depth combinations. The site scored in the optimal category for channel alteration and riparian zone width. The score for the site with regards to riparian zone width may have been falsely high due to the low water level and the deeply incised channel. The left bank of this site seemed to be highly altered by the past construction of a sewage treatment pumping station nearby; however, forested military lands dominated the right bank.

HSBP Habitat Score:
Score 87
Percent of statewide reference..... 44%
Estimated degree of attainment of aquatic life use ..... Nonsupporting

Figure 15. Dojo (Misgurnus anguillicaudatus) found at Lower Waikakalaua Site

The HSBP methodology showed the Lower Waikakalaua site to be impaired. Sampling at this site recovered only alien aquatic fauna. Topminnows, such as the common mosquito fish (*Gambusia affinis*), guppies (*Poecilia reticulata*) and mollies (*Poecilia* spp.) and green swordtails (*Xiphophorus helleri*) were sampled. Crayfish (*Procambarus clarkii*) and a dojo (*Misgurnus anguillicaudatus*) were also collected. The introduced grass shrimp, *Neocaridina denticulata sinensis*, were also abundant.

HSBP Biological Score:
Score 15
Percent of statewide reference..... 27%
Evaluation of aquatic life ..... Impaired

Lower Waikele Site

The Lower Waikele site scored in the "Medium" range for habitat quality, using the Hawaii Stream Visual Assessment Protocol (HSVAP). Turbidity was relatively low perhaps due to the input from multiple groundwater seeps into the stream. Conversely, the slower, deeper sections of the stream accumulated fine sediments both in the water column and on the bottom of the stream. Algal growth scored low throughout the segment due to a persistent algal scum on the rock substrate. The channel condition was naturalized after an obvious anthropogenic stream alignment. Channel flow did not seem to be highly impacted by artificial water withdrawals or discharges though one small intake pipe was identified, during the survey. Embeddedness scores ranged from medium in the segments with slower moving water to very high in the segments dominated by shallow riffles. The left bank was steep with little riparian area and had a two lane road within a few meters of the stream while the other side of the bank was dominated by alien grasses. Bank stability and riparian condition scores were low throughout the segment. The canopy cover scores were variable throughout the segment since the canopy ranged from closed to open. Although riffles and runs primarily dominated the site, habitat from cold-water groundwater seeps was also

available; therefore, available habitat scored in the high to very high range for all segments. The Litter/Trash metric consistently scored low since trash was evident throughout the site.

HSVAP Score:
Score ..... 1.2 out of 2.0
Average Habitat Rating ..... Medium

The Hawaii Stream Bioassessment Protocol (HSBP) habitat score for this site was "Partially Supporting." The site had suboptimal scores for habitat availability; however, the deeper pooled area of the site was not accessible for evaluation. Overall, the site scored borderline optimal for embeddedness, channel flow status and cobble/boulder vs. soil. One should note that the portion of the site that was slow, deep, stagnant and soil-laden was not included in this evaluation because the water was too deep for proper evaluation. Velocity-depth combinations were suboptimal. The optimal score for channel alignment did not clearly reflect the extent to which channel alignment and grading affected this section of the stream. Bank stability scores were poor, and the riparian vegetation width did not provide a sufficient buffer for the stream throughout the segment. The score for organic matter was optimal.

HSBP Habitat Score:
Score 119
Percent of statewide reference..... 60%
Estimated degree of attainment of aquatic life use ..... Partially Supporting

Figure 16. Berried Female 'opae 'oeha'a from Waikele Stream

The HSBP methodology showed the Lower Waikele site to be moderately impaired. This site was dominated by alien species. Only one native 'o'opu nakea (*Awaous guamensis*) and many native prawns (*Macrobrachium grandimanus*) were sampled. Many of the female native prawns were carrying eggs or "berried" (see Figure 15). Tahitian prawns (*Macrobrachium lar*) were also found at the site. Topminnows, such as the common mosquito fish, *Gambusia affinis*, guppies (*Poecilia reticulata*) and mollies (*Poecilia* spp.) have invaded the site. Bristlenose catfish (*Ancistrus sp.*), green swordtails (*Xiphophorus helleri*) and crayfish (*Procambarus clarkii*) were also collected. Introduced grass shrimp, *Neocaridina denticulata sinensis*, were also abundant. Although small mouth bass (*Micropterus dolomieu*) were sighted during previous investigations of the site and bass fishermen were also encountered, none were collected during this assessment.

HSBP Biological Score:
Score 17
Percent of statewide reference..... 31%
Evaluation of aquatic life ..... Impaired

Setting Management Goals Using Biological and Habitat Indicators

The Hawaii Stream Visual Assessment Protocol (HSVAP) and the Hawaii Stream Bioassessment Protocol (HSBP) are standardized methods used by the Hawaii Department of Health to assess stream habitat and biological quality in the state of Hawaii. The scores can be used to prioritize streams for restoration activities and identify both sources of degradation and the affected ecological components. The scores from this bioassessment will help quantify Waikele Stream's pollution problem and will be valuable in preparing the Total Maximum Daily Load (TMDL) and setting water quality restoration goals for the stream.

Water Quality Standards – Designated Uses, Narrative, and Numerical Criteria

Waikele Stream was placed on the Clean Water Act §303(d) List of Impaired Water bodies based on visual assessment that indicated the waterbody was exceeding nutrient and turbidity water quality criteria (USEPA 2002; Henderson 2002). The nutrient criteria are set for all Hawaiian streams (perennial and intermittent) in an effort to limit nutrient loading, which often leads to increased eutrophic conditions. Eutrophication is the process by which a body of water becomes enriched with organic material (NRC 2000). Eutrophication can cause hypoxic (low oxygen) or anoxic (no oxygen) conditions and other effects that can stress the flora and fauna in stream ecosystems. Consequently, a highly eutrophic stream is less likely to be capable of fully supporting the designated uses listed in the Water Quality Standards. As set forth in HAR §11-54-03(b)(2), the uses to be protected in the Class 2 reaches of Waikele Stream encompass "all uses compatible with the protection and propagation of fish, shellfish, and wildlife, and with recreation in and on these waters."

Turbidity measures water clarity, and waters with high turbidity levels are also less likely to support the above uses. Turbid water can be caused by many different types of pollutants, as well as biochemical activity, and can lead to many ecological problems. For instance, soil particles in the water column can block the light necessary for growth of algae that many of the native fish consume (Kido 1996a; 1996b; 1997). The chemicals that bind to these soil particles can also be toxic to aquatic animals that ingest them. Also, if the decreased water clarity was due to a toxic pollutant, fish and invertebrates could be directly affected when they respire through their gills.

The following TMDL implementation goals are set for Waikele Stream based on these designated uses:

> ***Class 2 Segments***
> *Aquatic life uses shall be supported in Waikele Stream; the habitat characteristics shall be improved at least into the range of values indicating partially supporting habitat, and the biological community shall be brought at least into the range corresponding to moderately impaired as measured by the HSBP.*
>
> ***Class 1 Segments***
> *Native breeding stock shall be protected in Waikele Stream; the habitat characteristics shall be in the range of values indicating supporting habitat, and the biological community shall be in the range corresponding to unimpaired as measured by the HSBP.*

Existing uses must also be considered when setting management goals. During the course of the biological assessments of Waikele Stream system, "Native Breeding Stock" was identified as an existing use of the Class 2 segment of Waikele Stream from the Waipahu Street Bridge to USGS gaging station number 16213000. Additionally, anecdotal evidence cited in various technical reports also suggests that "native breeding stock" exists or has existed since 1978 in other portions of the stream that are designated Class 2 (see section on Previous Studies in the Waikele Stream Watershed). Future studies should further investigate this situation and the possibility that native fish, specifically *Awaous guamensis*, are migrating and reproducing throughout the Waikele Stream System. 'Opae kala'ole (*Atyoida bisulcata*) were reported in Kipapa Stream in a 1996 study related to the Air Force POL pipeline (EA Engineering, Science, and Technology); however, none were detected in this study.

Biological diversity can be adversely affected by flow characteristics and release of invasive species into a stream despite water quality conditions (Englund 2002). Waikele Stream is an interrupted perennial stream as defined under HAR 11-54-01. The interrupted nature of Waikele Stream could negatively affect bioassessment scores at those sites where flow to the ocean is not continuous. These sites may be impaired due to natural and/or artificial flow interruptions (e.g. drought and/or diversions) rather than water quality degradation. Despite the fact that the Lower Waikakalaua, Upper Waikakalaua and Lower Kipapa sites were observed to be dry during part of the year, biological assessments were conducted at these sites. The Lower Waikele site is the only site that has a continuous connection with the ocean throughout the year. Therefore, this site may be the most appropriate for overall stream bioassessment scoring and setting management goals related to water quality.

The following tables display TMDL implementation goals for Waikele Stream that are consistent with the goals set for Waimanalo Stream (Smith 1998), Kawa Stream (Burr 2001b) and Kaneohe Stream (Burr 2001a) in order to protect designated uses (see Tables 4 and 5). Following this approach, management measures should be undertaken to ensure that the Upper Kipapa site maintains a score in the range of 150-200 (75-100% of reference) for habitat quality and improve the biotic integrity score from 15 (27% of reference) to the range of 35-50 (64-91% of reference) and the Lower Kipapa site maintains scores in the range of 100-150 (50-75% of reference) for habitat quality and 15-35 (27-64% of reference) for biotic integrity. The establishment of higher goals may be necessary to maintain native breeding stock in the Kipapa Tributary. The strategy for achieving these goals is unclear without future studies to document the presence and extent to which water quality degradation is the major source of impairment in this tributary. The Upper Waikakalaua site habitat score should improve from 92.5 (46% of reference) to within the range of 100-150 (50-75% of reference) and maintain a score between 15-35 (27-64% of reference) for biotic integrity. The Lower Waikakalaua site should improve from a habitat score of 87 (44% of reference) to a score in the range of 100-150 (50-75% of reference), and the biotic integrity score should continue to be within the range of 15-35 (27-64% of reference). The Lower Waikele site should maintain a score between 100-150 (50-75% of reference) for habitat quality and a score between 15-35 (27-64% of reference) for biotic integrity. These goal scores are for minimal support of designated uses. Higher scores may be necessary to support existing uses.

Table 4. TMDL implementation goals for lower Waikele Stream (Class 2).

Attribute	*Current score range*	*Goal score range*
Habitat characteristics	*87-119*	*100-150*
Biological metrics	*15-17*	*15-35*

If the Class 2 sections of Waikele Stream are able to reach the partially supporting range for habitat characteristics and the moderately impaired range for biotic integrity, they will more closely resemble the scores achieved by streams that maintain the highest quality of habitat and biota found on Oahu, although they will still remain considerably below the Hawaii reference streams. Once the target scores are met, Waikele Stream should be capable of supporting the designated uses set forth in HAR §11-54-03(b)(2). These scores may not be achievable without at least partial restoration of in-stream flow and control of alien species; however, these actions are beyond the scope of this report.

Table 5. TMDL Implementation Goals for the Headwaters of Waikele Stream (Class 1)

Attribute	*Current score*	*Goal score range*
Habitat characteristics	*161.5*	*150-200*
Biological metrics	*15*	*35-50*

The final figures in this report characterize the gaps between state reference stream conditions, the conditions in Waikele Stream and other streams for which we have established TMDLs. Numerous factors, including urbanization, agricultural development, lack of stream flow and introduction of alien aquatic species have contributed to the degradation of Waikele Stream. Despite this, Waikele Stream still has native species that are reproducing, reportedly migrating into the upper reaches of the stream and utilizing the stream's minimal habitat for their survival (see section on Previous Studies in the Waikele Stream Watershed). Restoration of water quality conditions to the level set by the State Water Quality Standards is an important step in maintaining the populations of native species that do exist.

Figure 17. Comparison of Stream Biotic integrity and Habitat Quality of State Reference Conditions to Waikele Stream

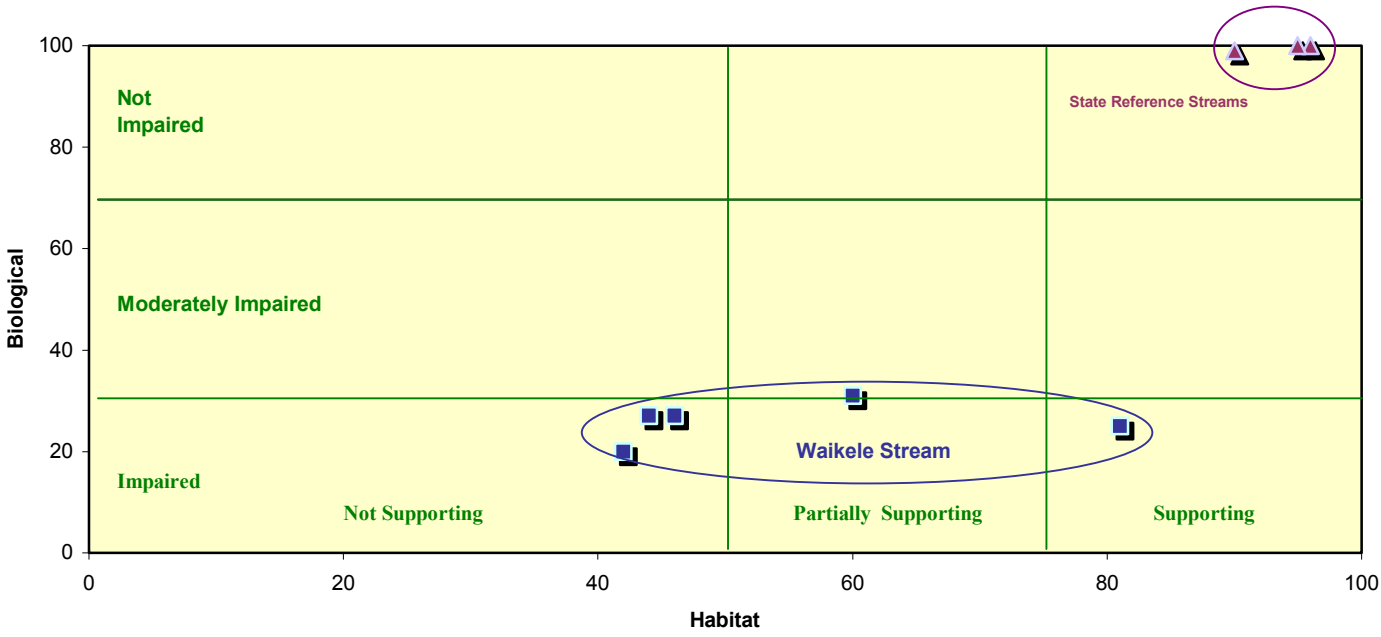
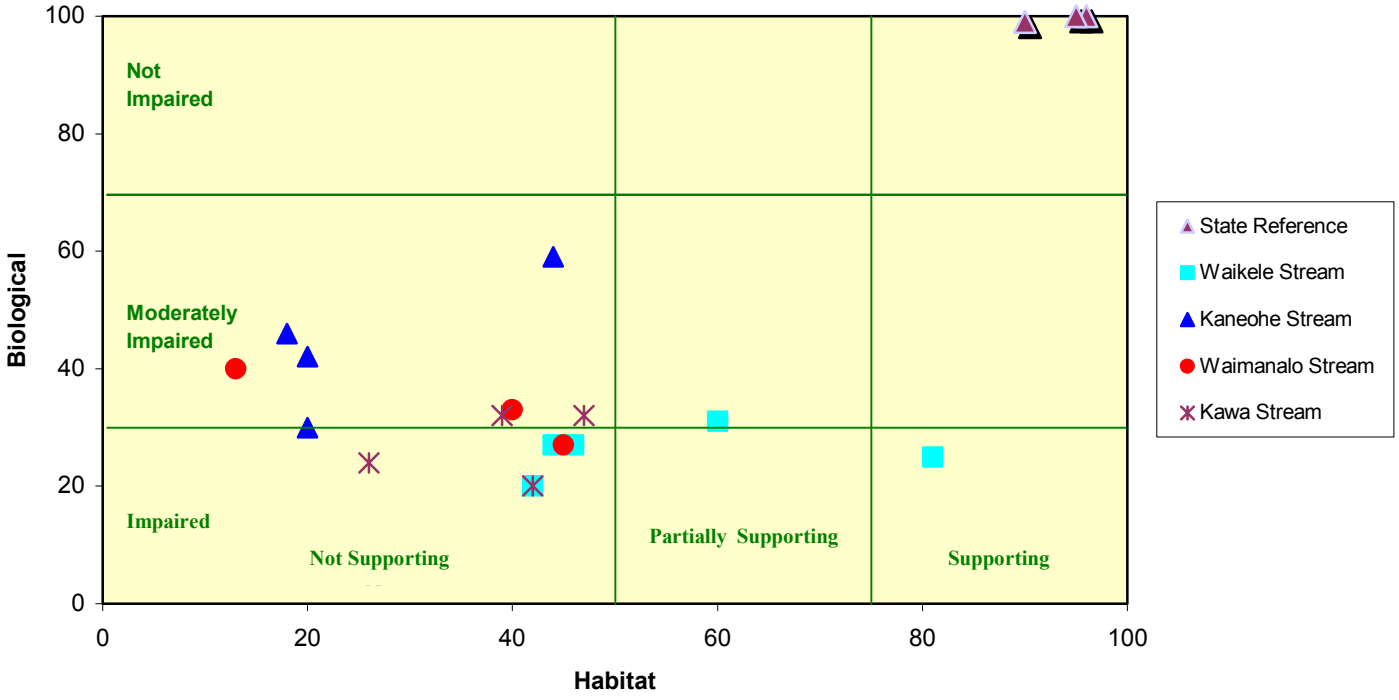


Figure 18. ***Comparison Chart of Data from all TMDL Bioassessment Sites in Hawaii***



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